

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization  
International Bureau



(43) International Publication Date  
11 January 2001 (11.01.2001)

PCT

(10) International Publication Number  
**WO 01/02885 A1**

(51) International Patent Classification<sup>7</sup>: **G02B 6/26**

(21) International Application Number: PCT/SE00/01373

(22) International Filing Date: 28 June 2000 (28.06.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:  
9902552-0 2 July 1999 (02.07.1999) SE

(71) Applicant (for all designated States except US): **PROXIMION FIBER OPTICS AB [SE/SE]**; Isafjordsgatan 9, SE-164 40 Kista (SE).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **ASSEH, Adel** [SE/SE]; Katarina Bangata 37, SE-116 39 Stockholm (SE). **SAHLGREN, Bengt** [SE/SE]; Norrholmsvägen 92, S-132 31 Saltsjö-Boo (SE). **STUBBE, Raoul** [SE/SE]; Kornvägen 21, S-182 75 Stocksund (SE).

(74) Agent: **AWAPATENT AB**; P.O. Box 45086, S-104 30 Stockholm (SE).

(81) Designated States (national): AE, AG, AL, AM, AT, AT (utility model), AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, CZ (utility model), DE, DE (utility model), DK, DK (utility model), DM, DZ, EE, EE (utility model), ES, FI, FI (utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KR (utility model), KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (utility model), SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

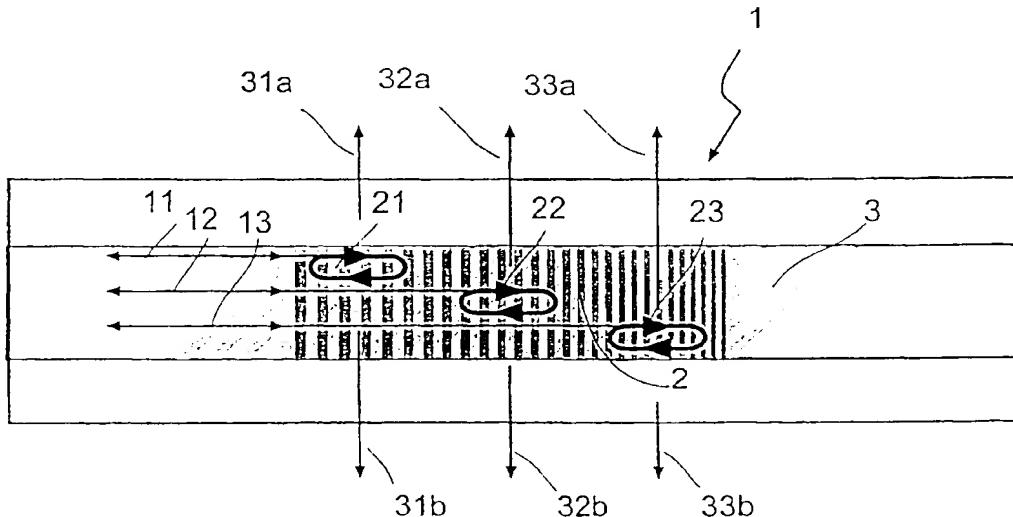
(84) Designated States (regional): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:

-- With international search report.  
-- Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: OPTICAL COUPLING



**WO 01/02885 A1**

(57) Abstract: A method and a device for coupling light to or from an optical waveguide, wherein a local resonance to a specific wavelength is provided in a portion of the waveguide intended for coupling the specific wavelength component of the light. Light coupling to or from the waveguide takes place at the portion with local resonance.

OPTICAL COUPLINGField of the Invention

The present invention relates to a method and a device for coupling light to or from an optical waveguide.

5

Background of the Invention

Light guiding in optical waveguides, and light guiding in optical fibres in particular, is a well-known technology for transporting energy and information in the form of light. For example, as in the case of optical fibres, one-dimensional optical waveguides are based on light guiding in a medium of cylindrical symmetry. The light guiding takes place in a core, which is surrounded by a medium having a lower refractive index, the so-called cladding, light guiding according to a simple model being obtained by means of repeated total internal reflections between the core and the cladding. However, the light can only propagate in certain predetermined directions, so-called modes, which are defined by certain phase conditions which must be met in connection with the propagation of the light. According to the standard model, these modes consist of eigensolutions to Maxwell's equations applying existing cylindrical boundary conditions.

If the cross-sectional dimension of the core is sufficiently small, the light can only propagate in a single such mode. An optical waveguide with this characteristic is called an optical monomode waveguide.

Monomode waveguides have certain important advantages over a waveguide permitting several modes (multimode waveguide). For example, the information transfer capacity of an optical monomode fibre, often called an optical single-mode fibre, is much greater than that of a multimode fibre when light is guided through a long

fibre. Another important advantage of a monomode waveguide such as a single-mode fibre is its lack of ambiguity. Apart from the polarisation state of the light, the characteristics of the light will be well-defined 5 along the entire waveguide. In particular, the intensity distribution of the light will be well-defined along the entire waveguide. This is extremely important in order to provide predictable operation of waveguide-based components. A detailed description of the characteristics of 10 the single-mode fibre is provided in, for example, L.B. Jeunhomme "Single-mode fiber optics: Principles and applications", Marcel Dekker, New York (1990).

Generally, several separate channels are utilised in order to increase the transfer capacity of an optical 15 waveguide, each channel consisting of a specific light wavelength. This technology is usually called wavelength-multiplexed transfer or WDM (Wavelength Division Multiplexing). A summary of the WDM technology is provided in G. E. Keiser, "A review of WDM technology and applica- 20 tions", Opt. Fiber Technol, 5, pp. 3-39, (1999). In connection with WDM it is thus desirable to be able to add and subtract single channels, i.e. single light wavelengths, to and from the waveguide.

A well-known technology for wavelength-selective 25 alteration of the propagation direction of light utilises optical phase gratings. An optical phase grating is a structure of essentially periodically varying refractive index in an optically transparent medium. A review of the technology is provided in, for example, M. C. Hutley 30 "Diffraction gratings", Academic Press, London (1982). When light is incident upon an optical phase grating a small part of the incident light is reflected by each 35 grating element (period). When a plurality of grating elements are arranged in succession (i.e. arranged in a phase grating) the total amount of reflected light will be the sum of all of these separate reflections. The part of the incident light that is reflected by each grating

element depends on the depth (amplitude) of the refractive index modulation of the phase grating, i.e. on the refractive index difference of the grating elements. The greater the modulation the greater the part of the incident light that is reflected by each phase element. If the propagation direction of the light which is incident upon a phase grating is essentially perpendicular to the grating, i.e. to the normal of the grating elements, the grating is said to be operating in the Bragg domain and is called a Bragg grating. As a result of the perpendicular incidence the light will be reflected essentially parallel to the direction of incidence (i.e. in the opposite propagation direction). The light which is reflected by each grating element will thus overlap the light reflected by all the other grating elements, thus giving rise to interference. In a monomode waveguide, all reflections within a certain angle cone will couple to the only mode (propagation direction) permitted by the waveguide. In the case of the wavelength where these reflections are in phase, constructive interference arises, and despite the fact that each grating element only provides a low intensity reflection, substantial reflection will be obtained for this wavelength from the grating as a whole. This wavelength, at which a substantial reflection is obtained from the grating as a whole, is called the Bragg wavelength  $\lambda_{\text{Bragg}}$  and is given (in connection with perpendicular incidence) by

$$\lambda_{\text{Bragg}} = 2n\Lambda$$

30

where  $n$  is the average value of the refractive index and  $\Lambda$  is the period of the phase grating. The reflectance for the Bragg wavelength is given by

35

$$R_{\text{Bragg}} = \tanh^2 \kappa l$$

where  $L$  is the length of the Bragg grating in the propagation direction of the light and  $\kappa$  is defined as

$$\kappa = \frac{4\pi\Delta n}{\lambda}$$

where  $\Delta n$  is the amplitude of the refractive index modulation. Since the refractive index modulation  $\Delta n$  typically is small ( $10^{-5}$  -  $10^{-3}$ ), the above expression of the reflectance can be expanded into a power series, whereby 10 it can be seen that the reflectance is approximately proportional to the square of  $\Delta n$ .

If the angle of incidence of the light upon the phase grating is not perpendicular, i.e. if the grating planes are inclined, the light will not be reflected in 15 the direction of incidence. The light reflected by each grating element will then only partially overlap the light reflected by the other grating elements and the interference effect will thus be less pronounced than in the Bragg domain.

20 A method for providing a phase grating in an optical waveguide is known from, for example, US-4,725,110 (Glenn et al). According to this method a waveguide is illuminated by ultraviolet light through an interferometer, resulting in periodic exposure of the waveguide, which 25 gives rise to a periodic alteration of the refractive index in the waveguide. This refractive index alteration remains in the waveguide subsequent to the exposure. By controlling the angle between the interfering, ultraviolet light rays the period can be chosen so that the 30 desired Bragg wavelength is obtained. The angles of incidence of the interfering, ultraviolet light rays are usually chosen to be symmetrically arranged relative to the axis of propagation of the waveguide in order to provide grating elements whose planes are oriented essentially at right angles to the propagation axis of the 35 waveguide, the grating thus operating in the Bragg

domain. This technology has been found to be most effective for waveguides in which the waveguiding structure is composed of germanium silicate, i.e. where the waveguiding structure is composed of quartz to which a certain 5 amount of germanium has been added.

US-5,042,897 (Meltz et al.) describes a device for coupling light from a waveguide with the aid of tilted (inclined) gratings, i.e. phase gratings having grating elements (refractive index variations) whose planes 10 intersect the propagation axis of the waveguide under an angle which is different from 90 degrees. These tilted gratings are provided by means of an interferometer as mentioned above by angling the same in relation to the propagation axis of the waveguide. The angle at which the 15 light will be coupled from the waveguide is determined by the angle of inclination of the grating elements in relation to the propagation axis of the waveguide (the transverse phase matching condition) as well as by the wavelength (the longitudinal phase matching condition).  
20 See, for example, R. Kashyap. "Fiber Bragg Gratings", Academic Press, London (1999). The tilted grating elements function as small, almost completely transparent, mirrors. The diameter of the mirrors (grating elements) is essentially equal to the diameter 25 of the waveguiding structure. In a single-mode fibre, for example, the waveguiding structure is composed of the core of the fibre, which usually has a diameter of about 10 micrometers. Since this diameter is not much greater than the wavelength of the light, the mirrors (grating 30 elements) will cause diffraction of the reflected light. Consequently, the reflected light will spread out in a cone around the angle defined by the angle of inclination of the grating elements. The transverse phase matching condition gives that this angle is about twice as large 35 as the angle of inclination. Since the grating elements reflect light which is partially overlapping, a certain wavelength will only give rise to constructive

interference if the light from each consecutive grating element is in phase with the light from the preceding grating element. This occurs at a certain predetermined angle, which is given by the longitudinal phase matching condition

$$\frac{2\pi N_{eff}}{\lambda} + \frac{2\pi n_{clad}}{\lambda} \cos\varphi_L = \frac{2\pi}{\lambda} \cos\theta_g$$

where  $N_{eff}$  and  $n_{clad}$  are the refractive indices of the waveguiding structure (core) and the substrate (cladding) respectively, the substrate being assumed, in the above expression, to have an infinite extension,  $\varphi_L$  being the output-coupling angle in the cladding, and  $\theta_g$  being the angle of inclination.

A further development of the above device having tilted gratings is described in US-5,061,032 (Meltz et al.). In this device the period of the tilted grating is not constant; rather, it varies along the propagation axis of the waveguide. For example, the period of the grating can increase or decrease linearly (or according to some other mathematical function) along the waveguide. A grating whose period is altered monotonically in this manner is called a "chirped" grating (chirp = frequency sweep). By utilising customised chirp functions it is possible to cause the output-coupling of a certain wavelength to provide a focal line extending transversely of the waveguide.

The above methods for coupling light from a waveguide with the aid of tilted gratings require the output-coupling angle to be large enough to prevent the occurrence of a total internal reflection between the substrate (cladding) and the surrounding material (outer cover). In the typical case of an optical fibre the output-coupling angle  $\varphi_L$  must be greater than about  $44^\circ$ , which requires an angle of inclination  $\theta_g$  of at least about  $22^\circ$ . For a certain modulation (amplitude) of the

grating, its efficiency will decrease as the angle of inclination increases. A further drawback is that the output-coupling will be extremely polarisation-dependent. One approach aimed at avoiding these drawbacks is 5 described in US-5,832,156 (Strasser et al). According to that document, a prism having the same refractive index as the cladding of a fibre can be utilised, the prism being brought into optical contact with the fibre with the aid of a contacting liquid. This technology permits 10 angles of inclination of less than 15° and thereby avoids the above drawbacks to some extent. The prism is also used for spatial separation of output-coupled wavelengths with the aid of the dispersion of the prism. However, this output-coupling has some remaining drawbacks. 15 Firstly, the resolution of wavelengths is limited by the fact that the chirp function only serves its intended purpose for a certain wavelength. Secondly, the limited length of the chirped grating causes significant diffraction in connection with small angles of 20 inclination. Thirdly, the coupling efficiency will be different for different wavelengths.

Accordingly, there is a need for improved devices and methods for coupling light to or from an optical waveguide, which essentially obviate the above-mentioned 25 problems.

#### Summary of the Invention

The main object of the present invention is to improve the possibilities of coupling light to or from 30 optical waveguides. This object is achieved by the use of a device and a method for light coupling of the kind stated in the appended claims.

A specific object of the present invention is to provide a device for wavelength-selective light coupling 35 to or from an optical waveguide, which has a spectral resolution that is substantially higher than that enabled by the prior art.

Another object of the invention is to provide a device for light coupling to or from an optical waveguide, enabling, in relation to the prior art, weaker and more precise coupling mechanisms while maintaining 5 coupling efficiency, so that, for example, a signal having a plurality of wavelength components which propagate in an optical waveguide can be analysed without affecting the signal as a whole to any significant extent.

A further object of the invention is to provide a 10 device for light coupling to or from an optical waveguide which is easy to produce and which is mechanically sturdy.

The invention is based on the insight that a resonance in an optical waveguide provides improved possibilities of coupling light in connection with the waveguide. Since a specific wavelength component is resonant 15 in a specific portion of the waveguide not only does one obtain more efficient coupling of the resonant wavelength component, but it is also separated spatially from the other wavelength components by means of a concentration 20 (local power density increase) in the resonant portion. An alternative way of describing this is that the coupling strength of a certain wavelength component, when 25 this wavelength component is coupled to or from the waveguide, increases significantly at the portion of the waveguide which is resonant to this wavelength component. Wavelength components of light propagating in a waveguide 30 can be separated spatially by the provision of a number of resonant portions in the waveguide, each portion being resonant to a specific wavelength component of the light. The resonance increases the coupling strength of a specific wavelength component in the corresponding resonance 35 portion. Wavelength selectivity is thus achieved by the spatial separation of said resonance portions, as well as by the increased coupling efficiency of the respective wavelength components at the corresponding resonance portion. Coupling of specific wavelength components to or

from the waveguide can thereby take place very advantageously at said resonant portions.

According to one aspect, the present invention enables output-coupling of a specific wavelength component from an optical waveguide, in which a plurality of wavelength components are propagating, without any significant impact on the wavelength components which are not being coupled. The wavelength-specific, local resonances in the waveguide will result in a local power density increase of the associated wavelength components, thereby permitting the utilisation of a coupling which is so weak that the impact on wavelength components having the original power density is negligible in most applications.

According to another aspect, the invention enables coupling of light to or from an optical waveguide, where different wavelength components are coupled to or from the waveguide at spatially separate portions. This has a number of very significant advantages such as the possibility of detecting different waveguide components in the output-coupled light with the aid of a detector matrix extending along the waveguide, and input-coupling of different wavelength components with the aid of a matrix of light sources, for example lasers having different emission wavelengths, extending along the waveguide. The invention also enables very smooth coupling of the respective waveguide components to an associated connecting waveguide at the corresponding resonant portion.

It is thus a major advantage of the invention that different waveguide components can be coupled to or from an optical waveguide, such as an optical fibre, at different positions along the waveguide.

A device according to the invention thus comprises at least one optical waveguide and means for coupling light to or from the optical waveguide and is provided with means for providing a portion in the optical waveguide which is locally resonant to a specific waveguide component. Moreover, said means for light coupling of

said wavelength component to or from the waveguiding structure are adapted to couple light at the resonance portion corresponding to said wavelength component.

According to a particularly preferred embodiment of 5 the invention, the waveguiding structure is a fibre core in an optical fibre, preferably an optical single-mode fibre, in which the local resonance portions are provided by a phase grating which is arranged in the fibre core. An essential feature is that the modulation depth, or 10 index amplitude, of the grating is sufficiently large to produce resonance, and thereby a local power density increase. The phase grating is preferably a Bragg grating with a monotonically increasing or decreasing period; a so-called chirped Bragg grating. The Bragg wavelength is 15 thus different in different parts of the grating, and, consequently, different wavelength components correspond with the Bragg wavelength at different portions of the grating. This means that the wavelength which corresponds with the local Bragg wavelength will exhibit resonance, 20 and thus increased power density, locally by virtue of the fact that the light is at least partially reflected back and forth by the grating in this portion. A plurality of spatially separate portions, in which light propagating in the fibre core exhibits resonance to a 25 certain wavelength component forming part of the light, are thereby obtained along the extent of the chirped grating. The deeper the index modulation of the chirped grating, the more the respective wavelength component is concentrated to the corresponding resonant portion.

30 Other objects and advantages of the present invention will be evident from the detailed description below of a number of preferred embodiments of the invention.

#### Brief Description of the Drawings

35 The invention will now be described in more detail by way of a number of preferred embodiments, with reference to the accompanying drawings, in which

Fig. 1 shows output-coupling from an optical fibre with the aid of a tilted phase grating according to the prior art;

5 Fig. 2 shows output-coupling from an optical fibre with the aid of a chirped, tilted phase grating according to the prior art, for obtaining a focal line of the output-coupled light;

10 Fig. 3 shows output-coupling from an optical fibre with the aid of a chirped, tilted phase grating, in which a prism is used for enabling smaller angles of inclination according to the prior art;

15 Fig. 4 is an outline diagram showing how resonance portions are created for three arbitrarily chosen wavelength components at different portions of an optical waveguide with the aid of a chirped Bragg grating;

20 Fig. 5 is an outline diagram showing wavelength selective output-coupling of light from a waveguide according to a first preferred embodiment of the present invention;

25 Fig. 6 is an outline diagram showing wavelength selective output-coupling of light from a waveguide according to a second preferred embodiment of the present invention;

30 Fig. 7 is an outline diagram showing wavelength selective output-coupling of light from a waveguide according to a third preferred embodiment of the present invention;

35 Fig. 8 is an outline diagram showing wavelength selective output-coupling of light from a waveguide according to a preferred embodiment in which a secondary waveguide is utilised as an intermediary step in connection with the output-coupling; and

40 Fig. 9 is an outline diagram showing input-coupling of light into a waveguide according to the present invention, in which the grating structure of the waveguide forms part of a light-generating means, for example a laser.

In the drawings, like or corresponding parts are designated by the same reference numerals.

Description of Preferred Embodiments

5 By way of introduction, the principle behind a first preferred embodiment of the invention will now be described using the prior art, shown in Figs 1-3, as a starting-point and with reference to Figs 4 and 5.

According to this embodiment, an optical waveguide, 10 for example an optical single-mode fibre 1, is provided with a chirped Bragg grating 2. The grating 2 has been manufactured according to the prior art. By virtue of the fact that the grating is formed with a monotonically increasing or decreasing period, i.e. it is chirped, different Bragg wavelengths are obtained at different portions along the grating. More specifically, the Bragg wavelength increases or decreases monotonically, in accordance with the period of the grating, as a function of the longitudinal position along the grating. For 15 illustration purposes the light propagating in the waveguide has arbitrarily been assumed to be composed of three wavelength components  $\lambda_1$ ,  $\lambda_2$  and  $\lambda_3$ , which are indicated by reference numerals 11, 12, and 13 in the Figures. By virtue of the fact that the grating 1 is 20 chirped different wavelength components 11, 12, 13 will correspond with the Bragg wavelength of the grating at different portions 21, 22, 23 along the grating. At these portions a strong reflection is obtained for the respective wavelength components and, consequently, wavelength 25 component 11, for example, will be reflected by the chirped grating in the area designated by reference numeral 21. However, the reflection is equally efficient in the case of light incident from the opposite direction and, consequently, the reflected light will be reflected 30 again by the grating in said area 21. A resonance effect occurs which causes the power density to increase locally for the wavelength component which corresponds with the 35

local Bragg wavelength in said area 21. Similarly, resonances are obtained for the other wavelength components 12, 13 at the resonance portions 22, 23 of the grating corresponding thereto. According to the invention, the 5 purpose of providing these resonance portions with increased power density is that light can be coupled from the waveguide in a wavelength-selective manner by means of output-coupling means which are arranged adjacent to (or operatively connected to) the waveguide at the 10 respective portions. A major advantage of an optical coupling according to the invention is that the coupling factor can be made so weak that wavelengths which are not resonant (do not have increased power density) are essentially unaffected. Another major advantage is that 15 different wavelengths can be output-coupled at different positions along the grating because of the fact that the resonance portions for the respective wavelength components are located at different positions along said grating. Correspondingly, input-coupling of light can be 20 provided in a wavelength-selective manner, whereby only wavelengths to which the grating is locally resonant are coupled to the waveguide. Fig. 5 shows a first preferred embodiment of the invention according to which said means for coupling light to or from the optical waveguide is 25 composed of a phase grating 3 having grating elements whose planes intersect the propagation axis of the wave-guiding structure under an angle which is different from 90 degrees, i.e. a tilted grating. This tilted grating is formed in such a way that the output-coupling is negligible at the positions and wavelengths where the chirped grating is not resonant. However, in the areas with 30 resonance (with increased power density) 21, 22, 23 efficient coupling is obtained. Since each wavelength component circulates in the respective portion, light 35 will be output-coupled in two directions 31ab, 32ab, 33ab. Output-coupling using titled gratings is polarisation-dependent and, consequently, in this case, output-

coupling mainly takes place for one of the two polarisation directions of the light. Two tilted gratings can advantageously be arranged in the waveguiding structure, one grating being turned 90 degrees about the propagation 5 axis of the waveguiding structure, output-coupled light being obtained in four lobes located opposite each other in pairs (not shown). Each opposite pair of lobes thus contains light with the same polarisation.

Fig. 6 shows a second preferred embodiment of the 10 invention. In this case, the coupling means comprises a Bragg grating 4 having an index modulation which decreases transversally across the grating. The amplitude (modulation depth) is thus lower at one edge 41 of the grating (radially) than at the opposite edge 42. This 15 means that when light is reflected against the grating it will have a direction of propagation which is somewhat different from the direction of incidence. In this application, this type of grating is referred to as a transversally asymmetrical phase grating. If the transversal 20 modulation depth variation is sufficiently large it will be possible to couple light to and from the waveguide with the aid of the transversally asymmetrical phase grating. Preferably, the chirped Bragg grating 2, i.e. the means for providing local resonances (locally 25 increased power densities) and the transversally asymmetrical phase grating 4 are the same grating, as illustrated in the Figure. The above-mentioned tilted grating can also be a transversally asymmetrical phase grating, a less pronounced tilt being required for obtaining light 30 coupling to or from the optical fibre. This reduces the polarisation-dependence of the coupling, which is an advantage in some applications.

Fig. 7 shows a third preferred embodiment of the 35 present invention. In the same way as in the previous embodiment, the local, wavelength-specific resonances 21, 22, 23 are created by a chirped phase grating 2 arranged in a waveguide 1. The optical waveguide is preferably an

optical fibre, most preferably an optical single-mode fibre. In this embodiment, said means for coupling light to or from the optical fibre is composed of means 61, 62, 63 for evanescent coupling of light to or from said fibre. The waveguiding structure 5 (the core) is arranged in the fibre in such a way that the surrounding cladding 6, on a chosen side of the core, is sufficiently thin to enable evanescent coupling to or from the fibre core 6a. By arranging the coupling means 61, 62, 63 in optical contact with the cladding 6a it is thus possible to output-couple light from the fibre by picking up the evanescent field extending outside said cladding. Correspondingly, it is also possible to input-couple light to the fibre through the evanescent field extending from said coupling means into the fibre core. The use of separate means 61, 62, 63 for evanescent coupling which are arranged at their respective resonance portions enables wavelength-separated coupling of light to or from the fibre core, each coupling means 61, 62, 63 coupling a certain wavelength component only. For example, wavelength component 11 is coupled to or from the waveguide by the coupling means 61 at the resonance portion 21, etc.

In a preferred variant of the above-mentioned embodiment, said means 61, 62, 63 for evanescent coupling comprise a fibre etalon of the Fabry-Perot type. Accordingly, light coupling is obtained only for the wavelengths which exhibit resonance in both the etalon and the associated resonance portion of the chirped grating. In this way, extremely high wavelength-selectivity can be obtained by using the present invention when coupling light to or from an optical waveguide.

A fourth embodiment of the invention is shown in Fig. 8. According to this embodiment, a secondary waveguiding structure 5a is used as an intermediary step when coupling light to or from an optical waveguide 1 such as an optical fibre. Preferably, the secondary waveguiding

structure 5a is provided with the same type of grating 2a as the grating 2 which is arranged in the main waveguide 5. If these gratings are two chirped gratings, substantially increased coupling strength between the secondary 5 waveguiding structure 5a and the main waveguide 5 is obtained for certain specific phase conditions. Suitable means 61, 62, 63 for output- or input-coupling of light are suitably arranged adjacent to (or operatively connected to) said secondary waveguiding structure. In 10 the Figure these are shown as means for evanescent coupling, but they can, of course, comprise an arbitrary, suitable means, the above embodiments being examples thereof. An important advantage of coupling light to or from a waveguide 1 with the aid of the secondary 15 waveguiding structure 5a as described above is that the coupling has no significant impact on light which is propagating in the main waveguide, except for those wavelength components which are being coupled. The evanescent coupling can be made sufficiently weak to 20 ensure that coupling of unintended wavelength components is essentially negligible. Another advantage of this embodiment is that the requirement of deep index modulation of said phase grating is not as strict, which, in some cases, is an advantage from a manufacturing point of 25 view. In addition, it may be advantageous to provide the above-mentioned gratings (chirped gratings) with different modulation depths, while the gratings are the same in other respects. In that way, the operation of the optical coupling can be customised even more precisely 30 for a certain application.

A preferred embodiment for input-coupling of light into an optical waveguide according to the present invention is illustrated in Fig. 9. In this case, too, said means for creating local, wavelength-specific resonance 35 portions are represented by a chirped phase grating 2. In the Figure, said means for coupling light to or from the optical waveguide are represented by a tilted grating 3.

The Figure shows three separate light sources 71, 72, 73, lasers for example, which emit three different wavelength components 11, 12, 13 of light. The emitted light is coupled into the waveguide 1 at the resonance portion 21, 5 22, 23 corresponding to the respective wavelength components. Suitably, some type of focusing optics 81, 82, 83 are used for this input-coupling. It is particularly preferred that the respective resonant portions 21, 22, 23 in the waveguide perform the function of one of the cavity mirrors in a laser. In that case, the above-mentioned 10 light sources 71, 72, 73 comprise a light-generating medium and one of the mirrors of the laser cavity, feedback, and thus laser action, being provided with the aid of the resonance in the waveguide, which resonance serves 15 as a feedback cavity mirror in the laser. A major advantage of this embodiment is that the emission wavelength of the laser will be locked to the wavelength to which the corresponding portion of the waveguide is resonant, since sufficient feedback will occur only at this wavelength. 20 Naturally, a separate, external laser can be used, the emitted wavelength of the laser being coupled into the waveguide at a portion which is resonant to this wavelength.

An alternative way of providing output-coupling of 25 light is to bend said waveguide, whereby a controlled leakage of light from the waveguiding structure is obtained. The waveguide component which is coupled from the waveguide at a certain position along the waveguide can then be controlled by varying the bending. An optical 30 fibre can, for example, be wound onto a cylinder body, said control being effected by expanding or contracting the cylinder body. In principle, input-coupling of light by bending the optical fibre is also possible, although this is somewhat more difficult from a technical point of 35 view.

It should be noted that the wavelength components stated above can, but need not, in themselves comprise

several discrete wavelengths. For example, it is conceivable to use an optical coupling in which signals in one incoming optical fibre is to be separated into three outgoing optical fibres, signals which are to be coupled to 5 the first outgoing fibre forming part of the first wavelength component, etc.

## CLAIMS

1. A method of coupling light to or from an optical waveguide (1), comprising the steps of
  - 5 - establishing, in a portion of said waveguide intended for coupling a specific wavelength component (11, 12, 13) of the light, a local resonance (21, 22, 23) to said wavelength component, and
  - 10 - coupling said wavelength component to or from the optical waveguide at said portion with local resonance.
2. A method according to claim 1, wherein a plurality
  - 15 of spatially separate portions with local resonance to different wavelength components are established in the optical waveguide.
3. A method according to claim 1 or claim 2, wherein
  - 20 there is established local resonance to a specific wavelength component, selected from a plurality of wavelength components forming part of the light, in the portion intended for coupling said specific wavelength component.
- 25 4. A method according to any one of the claims 1 to 3, wherein there are established local resonances to a continuum of wavelength components, which resonances are distributed in wavelength-specific portions along the waveguide.
- 30 5. A method according to claim 4, wherein said local resonances are established by providing a chirped grating (2) in said waveguide.
- 35 6. A method according to any one of claims 1 to 5, wherein the coupling of light to or from the optical

waveguide is effected by means of a phase grating (3) having grating elements whose planes intersect the propagation axis of the waveguiding structure at an angle which is different from 90 degrees.

5

7. A method according to any one of claims 1 to 5, wherein the coupling of light to or from the optical waveguide is effected by means of a transversally asymmetrical phase grating (4).

10

8. A method according to any one of claims 1 to 5, wherein the coupling of light to or from the optical waveguide is effected by means of a bending of the optical waveguide.

15

9. A method according to any one of claims 1 to 5, wherein the coupling of light to or from the optical waveguide is effected by means of evanescent light coupling.

20

10. A method according to claim 9, wherein said coupling of light to or from the optical waveguide is effected by arranging a fibre etalon of the Fabry-Perot type adjacent to the optical waveguide, thereby enabling light coupling to or from the optical waveguide only of those wavelength components which meet the resonance conditions of said fibre etalon.

25

11. A method according to any one of the preceding claims, wherein a secondary waveguiding structure (5a) is utilised as an intermediary step when coupling light to or from said optical waveguide.

30

12. A method according to claim 11, wherein the coupling between the secondary waveguiding structure and said optical waveguide is an evanescent coupling.

13. A device for light coupling, which device comprises at least one optical waveguide (1) having a waveguiding structure which is adapted to guide light along a predetermined propagation axis, means for coupling light to or from the optical waveguide, characterised in that it comprises means for providing a portion in the optical waveguide with local resonance (21, 22, 23) to a specific wavelength component (11, 12, 13) of said light, said portion being associated with a resonance to a specific wavelength component, and that said means for coupling light to or from the optical waveguide are adapted to couple said wavelength component to or from the optical waveguide at the resonance portion associated with said wavelength component.

15

14. A device according to claim 13, wherein said means for providing a portion with local resonance comprises a phase grating (2) arranged in the waveguiding structure.

20

15. A device according to claim 14, wherein said phase grating is a chirped grating, resonances being provided for a continuum of wavelength components in wavelength-specific portions along the chirped grating.

25

16. A device according to any one of claims 13 to 15, wherein said means for coupling light to or from the optical waveguide comprises a phase grating (3) having grating elements whose planes intersect the propagation axis of the waveguiding structure at an angle which is different from 90 degrees.

30

17. A device according to any one of claims 13 to 15, wherein said means for coupling light to or from the optical waveguide comprise a transversally asymmetrical phase grating (4).

18. A device according to any one of claims 13 to 15, wherein said means for coupling light to or from the optical waveguide comprise means (61, 62, 63) for evanescent coupling of light to or from the optical waveguide.

19. A device according to any one of claims 13 to 15, wherein said means for coupling light to or from the optical waveguide comprise a bending of the optical waveguide.

20. A device according to claim 18, wherein said means for coupling light to or from the optical waveguide comprise a fibre etalon of the Fabry-Perot type arranged adjacent to the optical waveguide for providing evanescent light coupling between the fibre etalon and the optical waveguide, thereby enabling light coupling to or from the optical waveguide only of those wavelength components which meet the resonance conditions of the fibre etalon.

21. A device according to any one of claims 13 to 20, further comprising a secondary waveguiding structure (5a) to which light is coupled, said secondary waveguiding structure constituting an intermediary step when coupling light to or from said waveguide.

22. A device according to claim 21, wherein both the secondary waveguiding structure (5a) and the main optical waveguide (1) comprise a chirped grating (2, 2a).

23. A device according to any one of claims 13 to 22, wherein the optical waveguide is an optical fibre.

24. A device according to claim 23, wherein the optical fibre is a single-mode fibre.

Prior Art  
Fig. 1

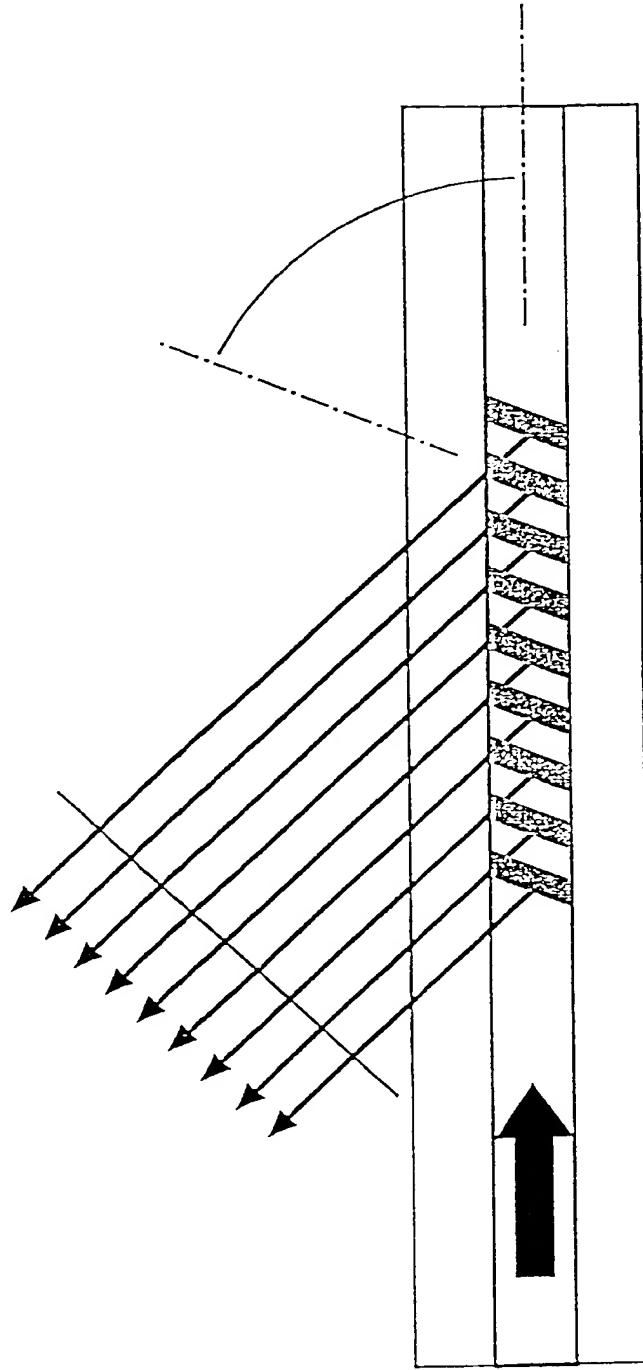
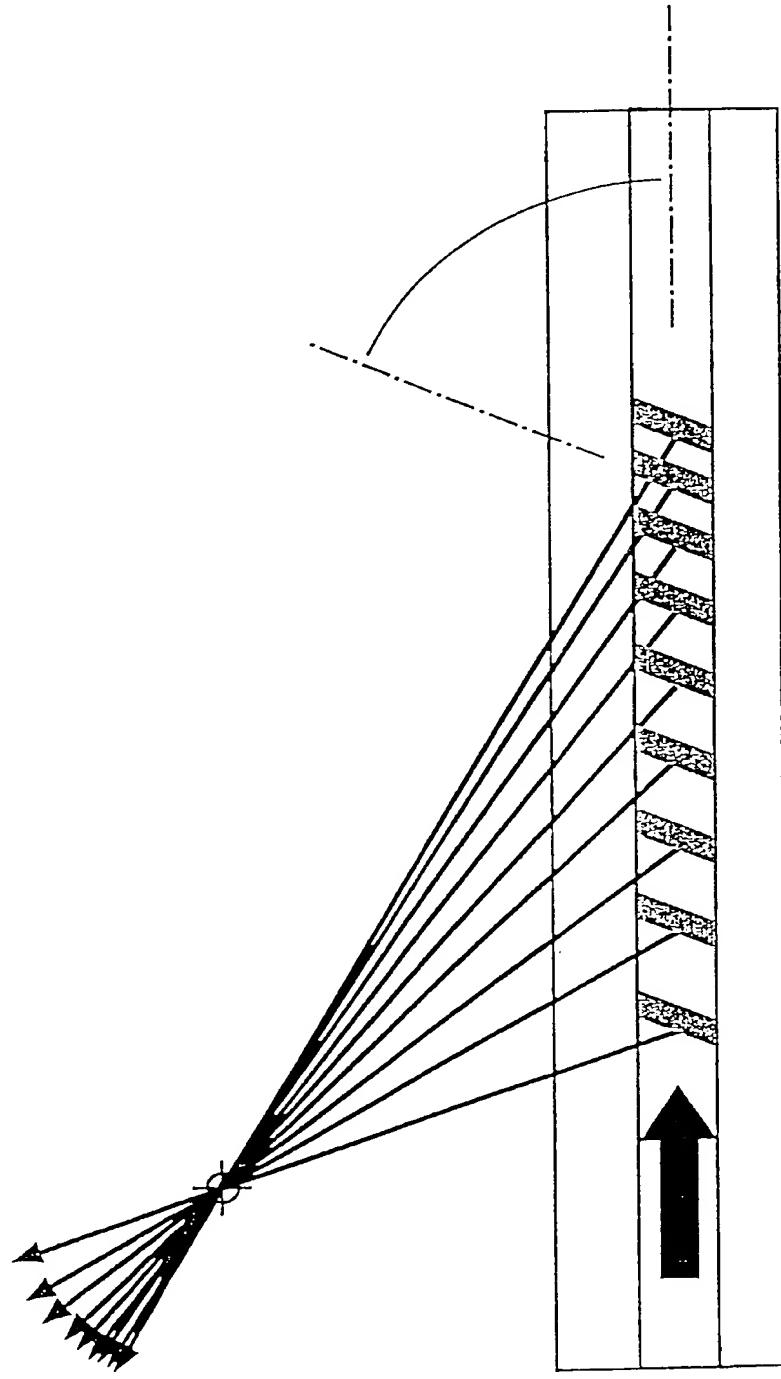
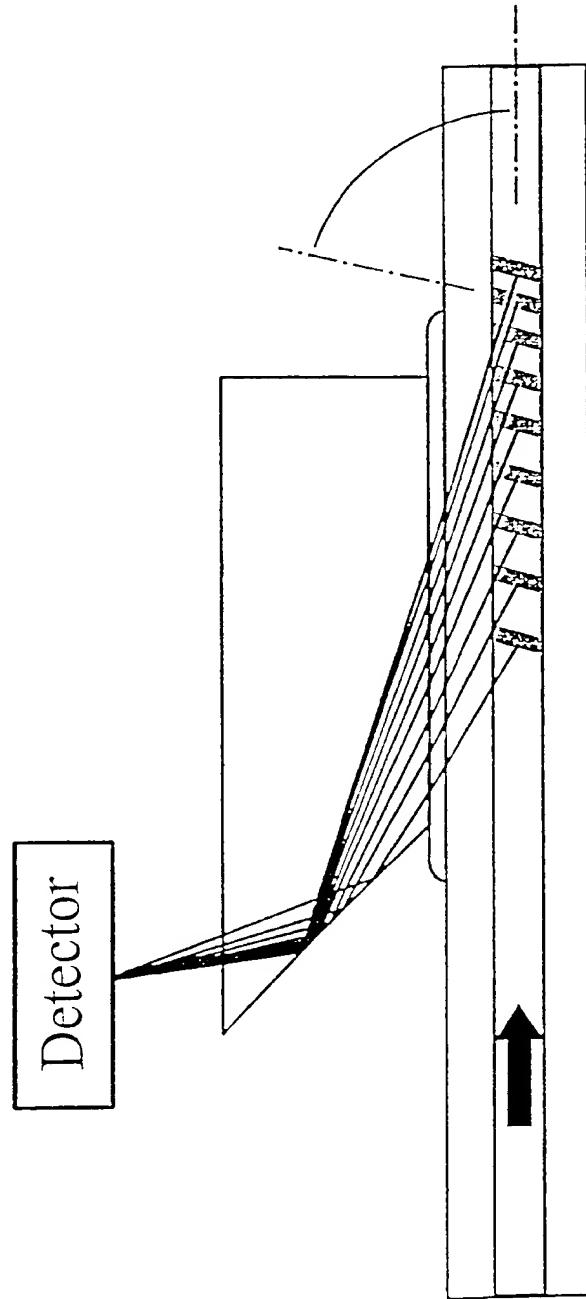


Fig. 2  
Prior Art



Prior Art  
Fig. 3



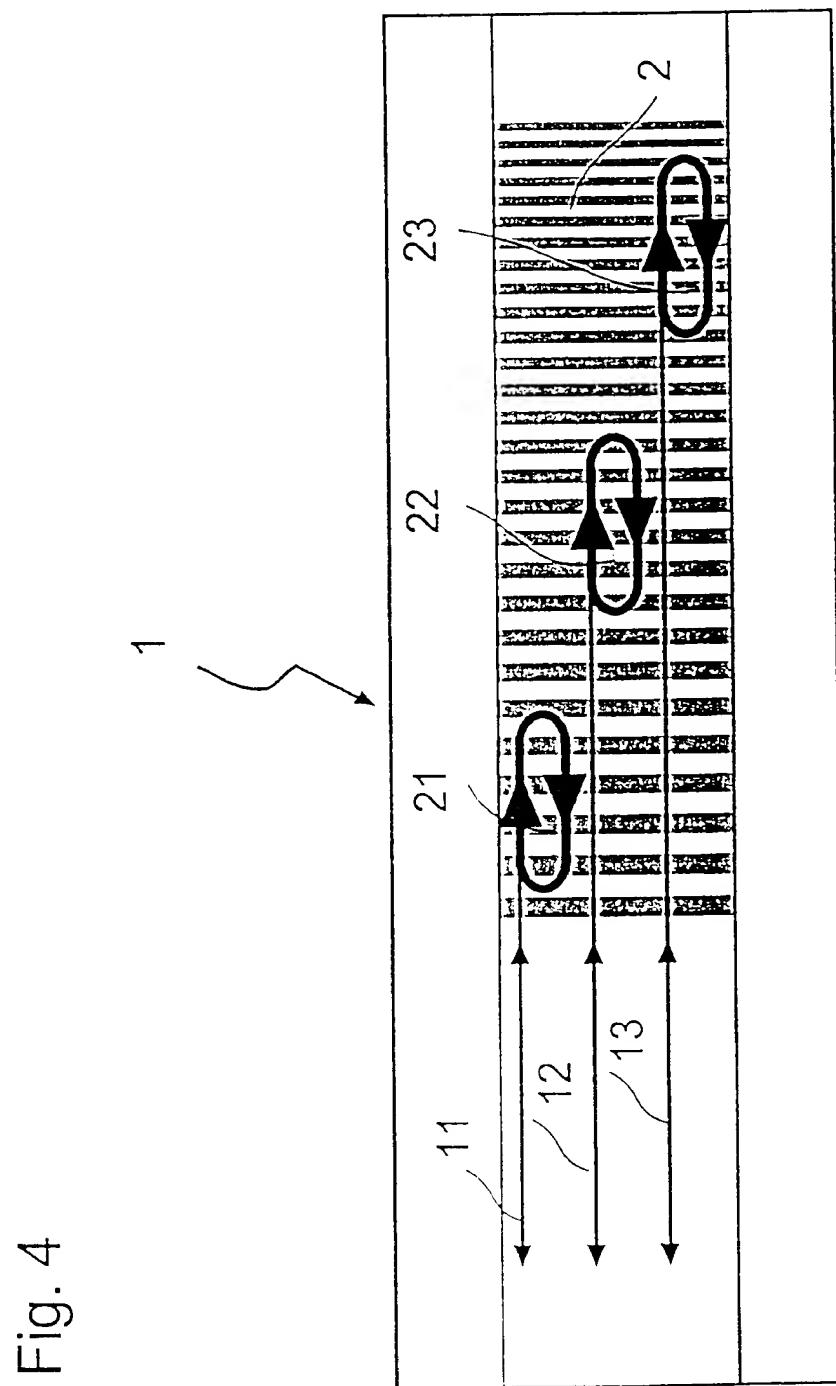


Fig. 4

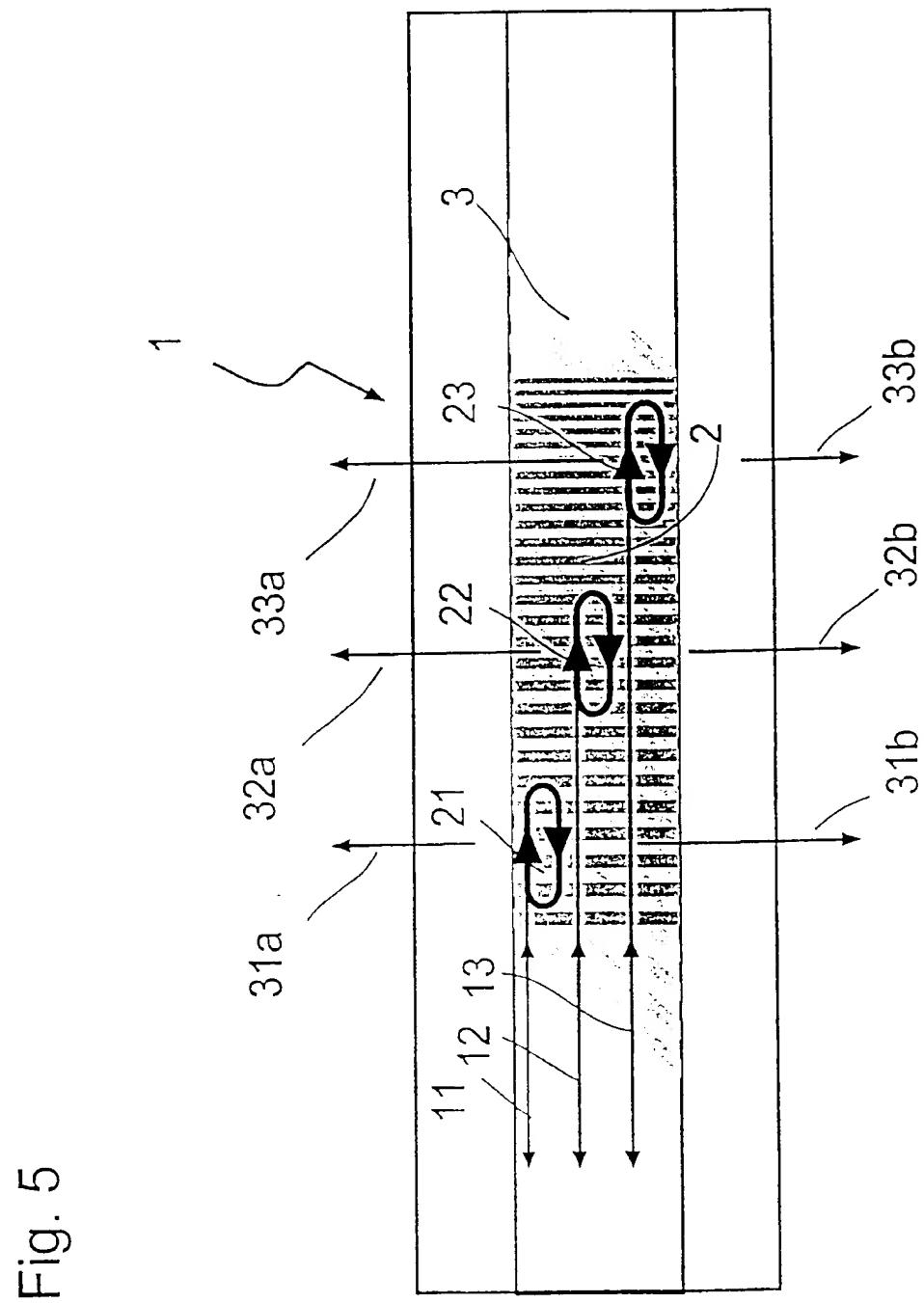


Fig. 5

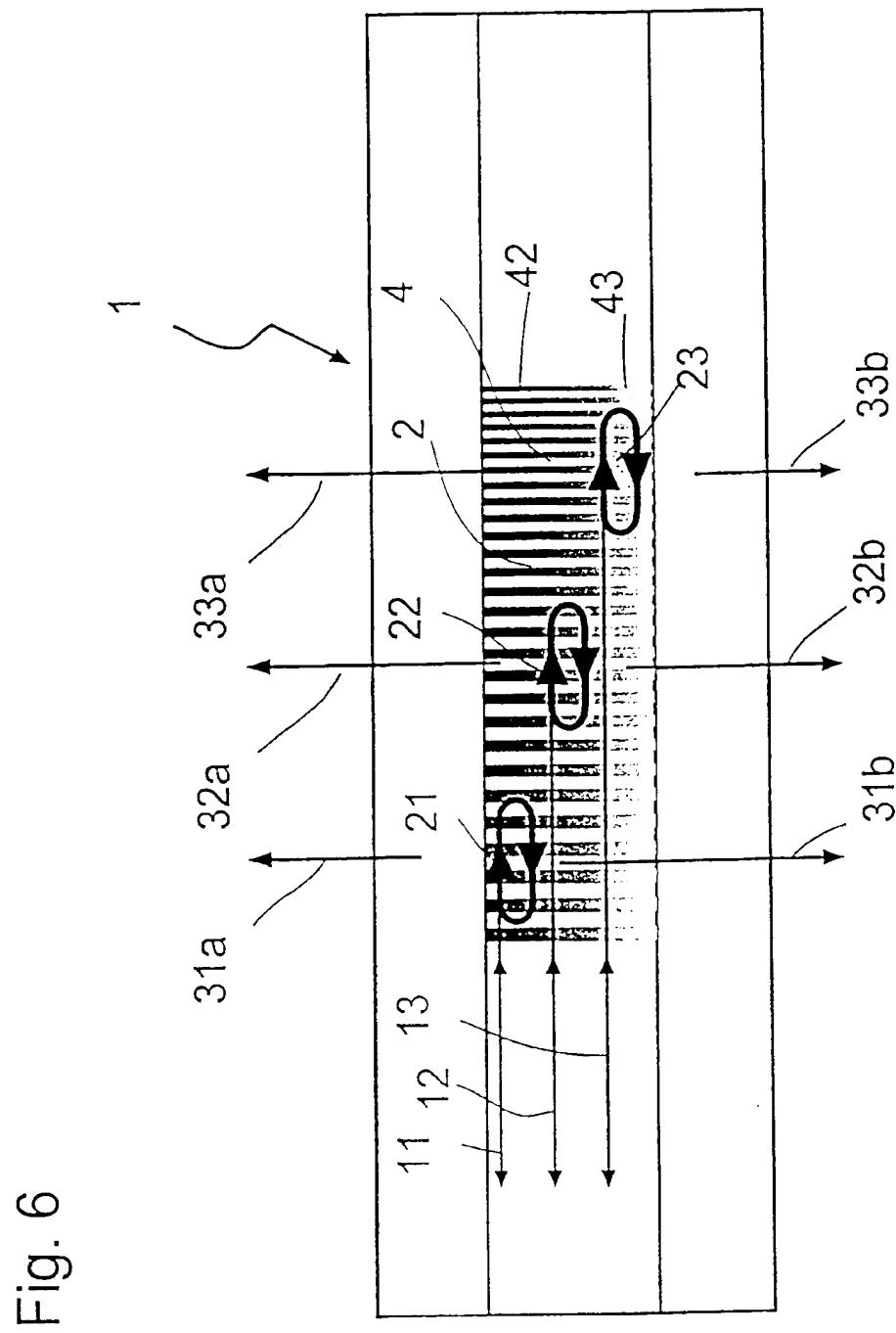


Fig. 6

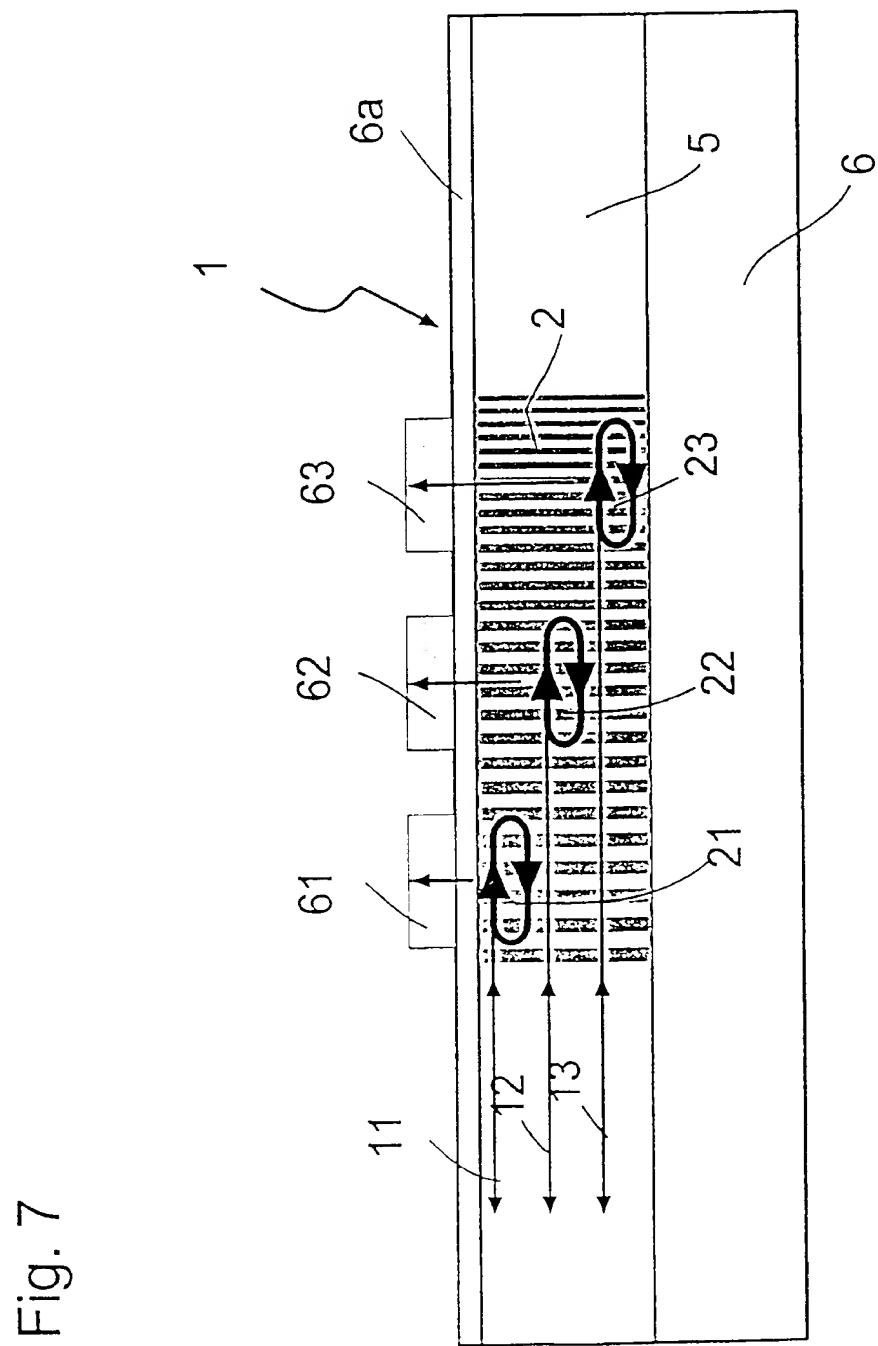
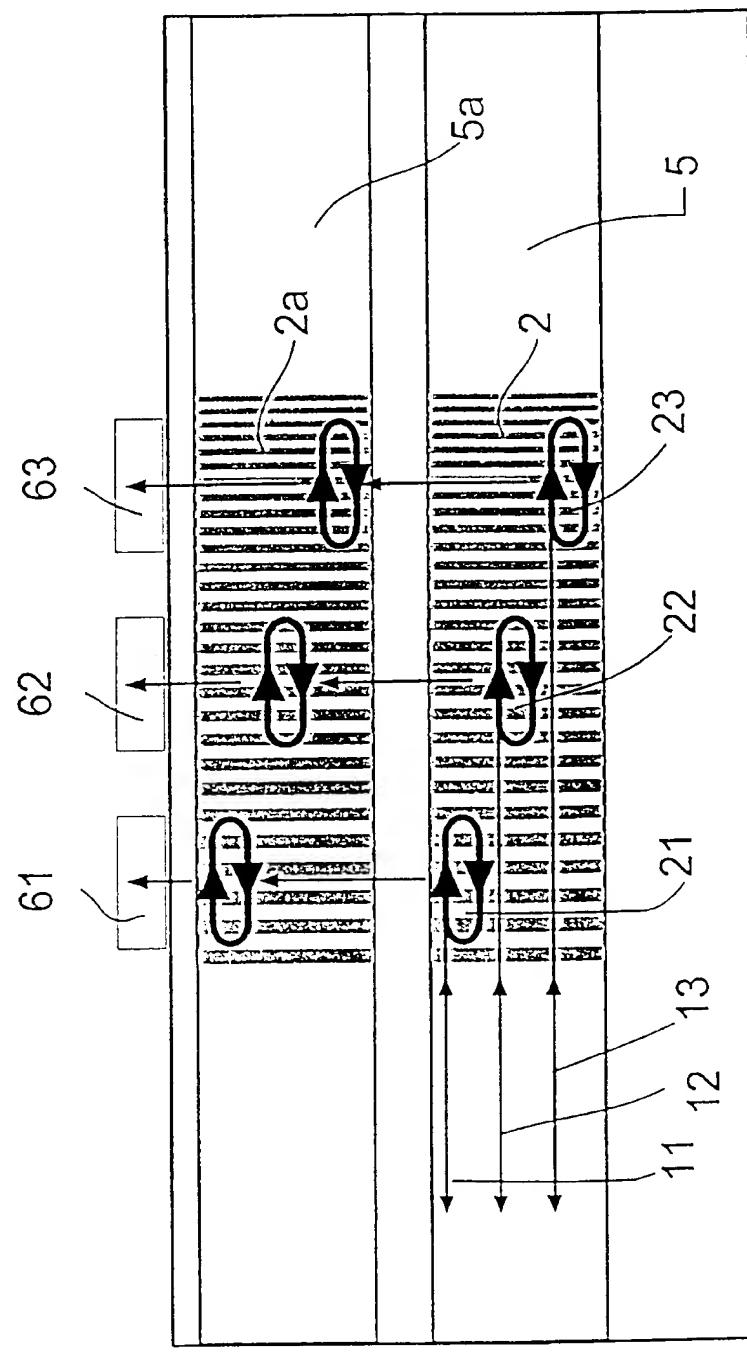


Fig. 7

88



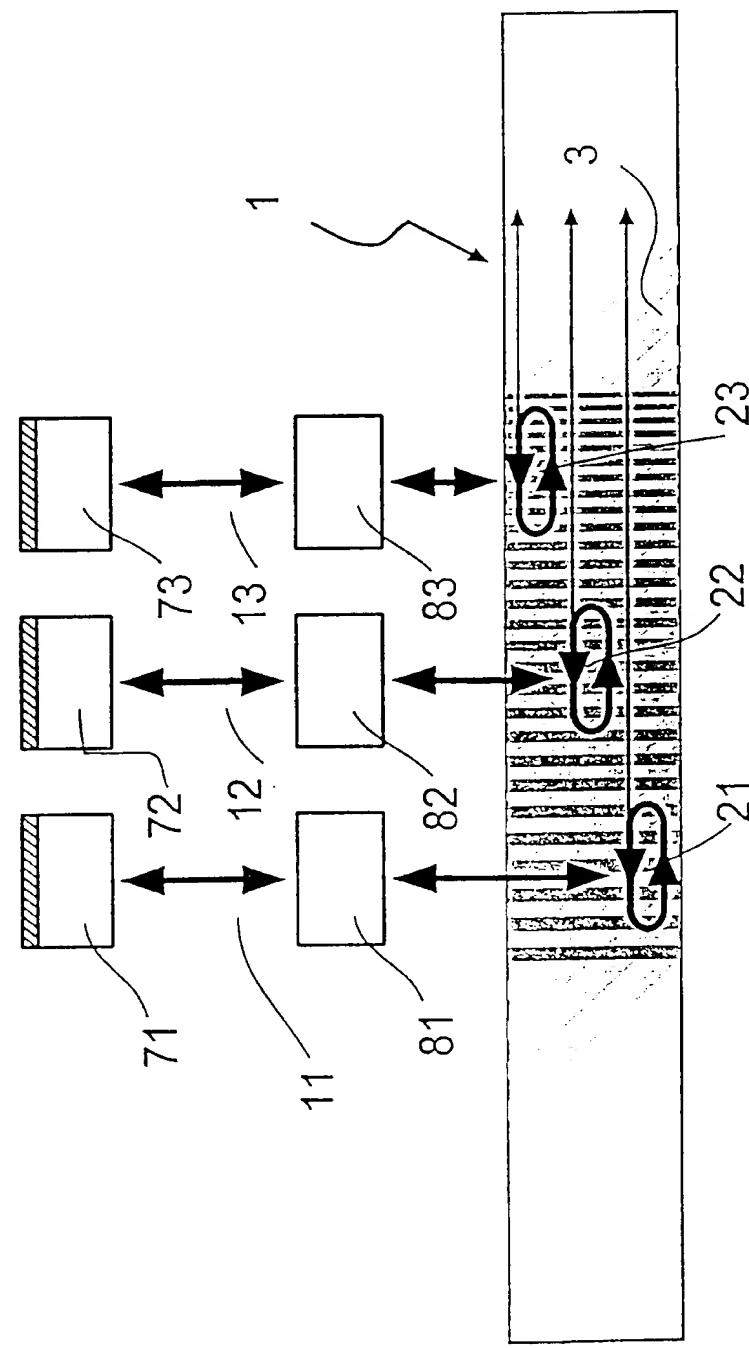


Fig. 9

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 00/01373

## A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G02B 6/26

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G02B, H01S

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0569174 A1 (AMERICAN TELEPHONE AND TELEGRAPH), 10 November 1993 (10.11.93)  --	1,13
A	US 5903690 A (DMITRY S. STARODUBOV ET AL), 11 May 1999 (11.05.99)  -----	1,13

 Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search	Date of mailing of the international search report
<u>21 November 2000</u>	<u>29-11-2000</u>
Name and mailing address of the ISA Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Authorized officer  <u>Magnus Westöö/MP</u> Telephone No. + 46 8 782 25 00

**INTERNATIONAL SEARCH REPORT**

Information on patent family members

02/11/00

International application No.

PCT/SE 00/01373

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP 0569174 A1	10/11/93	CA	2092589 A,C	06/11/93
		DE	69303857 D,T	20/02/97
		JP	2816291 B	27/10/98
		JP	6021536 A	28/01/94
		US	5237576 A	17/08/93
<hr/>				
US 5903690 A	11/05/99	AU	6839096 A	26/02/97
		CA	2201371 A	13/02/97
		CN	1159229 A	10/09/97
		EP	0784217 A	16/07/97
		RU	2095902 C	10/11/97
		RU	2097803 C	27/11/97
		US	5838700 A	17/11/98
		WO	9705511 A	13/02/97
		AU	710448 B	23/09/99
		JP	11506270 T	02/06/99
<hr/>				